Memorandum

U.S. Department of Transportation
FEDERAL AVIATION ADMINISTRATION

Subject:	INFORMATION: Policy for Time Limited Dispatch (TLD) of Engines Fitted with Full Authority Digital Engine Controls (FADEC) Systems	Date:	June 29, 2001
From:	Manager, Engine and Propeller Directorate, Aircraft Certification Service, ANE-100	Reply to Attn of:	Gary Horan, 781 238-7164 or gary.horan@faa.gov
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FEDERAL AVIATION ADMINISTRATION (FAA) POLICY FORTIME LIMITED DISPATCH (TLD) OF ENGINES FITTED WITH FULL AUTHORITY DIGITAL ENGINE CONTROL (FADEC) SYSTEMS

REVISION 1 CHANGES:

Section 5. Definitions. Removed the reference to "On-Condition" and "Condition Monitoring" maintenance strategies and revised the applicable text to address the maintenance strategies in terms of "task oriented" strategies. Added a definition of software integrity.

Section 6. Background. Added this section to provide information on TLD and describe the various ways in which TLD has been approved during previous engine and aircraft certification programs; how it has been approved for in-service operations; and the approach to be used for future TLD approvals.

Section 8. Discussion. Revised this section to indicate the documentation for TLD approval at engine certification, aircraft certification, and in-service operations.

Section 9. System Model. Rewritten extensively to provide a more complete description of the full-up and single-fault system models used in the TLD analysis and their outputs.

Section 13. Dispatch Intervals. Revised to add the fourth category of faults, manufacturer/operator defined dispatch, introduced after the issue of the original TLD policy. Simplified the maximum operating time allowance for short time faults in Entry Level applications from "150 flight hours or 10 days, whichever occurs first," to "125 flight hours."

Section 14. Maintenance Strategies. Revised to remove reference to "On-Condition" and "Condition Monitoring" maintenance strategies. Also, revised to emphasize that the authorization for the Principal Maintenance or Avionics Inspector (PMI/PAI) to temporarily extend the approved dispatch interval must be stated in the TLD authorization notes. The section has been considerably expanded to address the various maintenance approaches that can be used in conjunction with TLD operations.

Section 16. Engine-Aircraft Interface. Considerably revised and expanded to provide guidance to the engine manufacturer to include TLD information in the engine installation manual and provide guidance to the installer regarding the part 25 development assurance integrity requirements relating to any installer-provided fault recording devices.

Section 17. Field Experience. This section has been deleted from this policy because most of the information is no longer applicable or useful. The information that is still useful has been moved to Section 13 of this policy.

Table 1. TLD Approval. Added Table 1 to indicate the various documentation associated with FAA Engine Certification Office approval of TLD as part of engine certification; FAA Flight Standards Aircraft Evaluation Group approval of TLD at aircraft certification; and FAA Flight Standards Field Inspectors approval of TLD operations for a particular operator.

Table 2. Typical ALS Entry for TLD Limitations. Added Table 2 to show a typical Airworthiness Limitations Section entry that might be used for the TLD associated limitations.

Table 3. Maximum Operating Times for TLD Operations. Changed the short time limitation to be specified in flight hours only; changed the long time interval to have the limitation specified in exposure

time in flight hours - so that the short time and long time limitations are both given in flight hours; added the fourth dispatch category to the figure with an accompanying Note 2.

Table 4. Maximum Operating Times for TLD Operations Associated with the "MEL Maintenance Approach" and "Inspection/Repair Maintenance Approach." Added Table 4 to show the time limitations for both the short time and long time fault conditions associated with the maintenance approach used to address those fault categories.

Figure 1. Typical Data Presentation Showing LOTC Rate as a Function of Short Time and Long Time Operating Hours. Added Figure 1 to show the typical graph used to substantiate the analysis for compliance with the requirement for equivalent or better reliability than the hydromechanical technology of early systems.

Figure 2. Typical Aircraft System Configurations. Added Figure 2 to show the typical aircraft avionics system associated with FADEC system maintenance information and displays.

FEDERAL AVIATION ADMINISTRATION (FAA) POLICY FOR TIME LIMITED DISPATCH (TLD) OF ENGINES FITTED WITH FULL AUTHORITY DIGITAL ENGINE CONTROL (FADEC) SYSTEMS

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1. **PURPOSE.** This document provides FAA policy for obtaining type design approval for an airworthiness limitation under part 33 of Title 14 of the Code of Federal Regulations (14 CFR part 33), relating to dispatch of engines with full authority digital engine control (FADEC) systems in a degraded condition with respect to redundancy. This airworthiness limitation is commonly referred to as time limited dispatch (TLD) for engines with electronic engine control systems, which have some level of redundancy. This policy does not constitute a new regulation and does not establish a binding norm.

2. **SCOPE.** This document applies to type design approval for TLD for engines fitted with FADEC systems, when these systems are to be dispatched with faults present for limited time intervals before maintenance actions are required. The objective of this policy is to define the various dispatch categories and corresponding maintenance intervals to provide a control system that achieves overall compliance with the applicable airworthiness requirements of part 33. TLD operations have been applied to FADEC-equipped engines used in multi-engine aircraft applications, particularly those engines used in part 25 aircraft. The TLD requirements and limitations for those multi-engine aircraft discussed in this policy should be acceptable in single engine aircraft applications. However, the criteria used to establish acceptable TLD operations may need to be reviewed for those other applications. For example, it has been

accepted that single or multi-engine aircraft certified to part 23 requirements (and not certified to part 25 requirements) may only have to achieve a 40,000 hour "average reliability" for the engine control systems. This reliability level is considered equivalent to the mechanical engine control systems currently being used in part 23 aircraft. Thus, it may be acceptable for part 23 aircraft to dispatch with faults in the FADEC engine control systems that result in a control system loss-of-thrust-control (LOTC) or loss-of-power-control (LOPC) rate of less than the 10,000 hour lower limit allowed in part 25 applications. For part 23 applications, a lower limit for the LOTC rate of approximately 4,000 hours may be acceptable. The Engine and Propeller Directorate is currently reviewing the criteria for these other applications. The Engine and Propeller Directorate may issue additional or revised TLD policy to include the appropriate information for these other applications after the requirements have been established. This review of control system reliability and availability requirements for single engine aircraft applies to both reciprocating and turbine engines. The engine control system reliability and availability requirements should be the same for both turbine and reciprocating engines when those engines are targeted for the same type of aircraft application. The FAA is developing a separate TLD policy for engines targeted for airplanes certified under part 23 and operated under part 91 or part 135.

3. **CANCELLATION.** This document supersedes FAA policy on TLD of engines fitted with FADEC systems issued on October 28, 1993.

4. **RELATED SECTIONS.** Sections 33.4, 33.5, 33.19, 33.28, 33.91(a), 43.16, 91.213(d), 121.303(d), 121.627, 121.628, and 135.179.

5. **DEFINITIONS.**

a. Adequate Software Integrity. For the purposes of this policy, "adequate software integrity" level means that the software level used in the particular electronic unit being discussed is equivalent to DO-178B, level C, unless a higher level is specified.

b. Central Processor Unit (CPU). The CPU is the main processor(s) within the electronic engine control that receives conditioned input data, processes and manipulates the data, and provides output commands to control the engine in accordance with stored algorithms.

c. Cross-Channel Data Link (CCDL). The CCDL is the digital data link that transfers data between the functionally redundant CPUs in their respective channels.

d. Dispatch Interval. The dispatch interval is the maximum time interval approved by the FAA for dispatch with faults present in the system before corrective maintenance is required.

e. Entry Level System. An entry level system is a FADEC system that has not reached maturity as defined in this policy.

f. FADEC Family. FADEC systems can be considered to be a FADEC family when the electronic engine controls are related due to an overwhelming majority of common parts, similar design and manufacturing technology, and similar engine installation.

g. FADEC System. The FADEC system controls the operation of the engine over the entire operating range, usually from engine start to maximum power or thrust. The FADEC system consists of the electronic engine control (EEC), fuel metering unit (hydromechanical control), sensors, actuators, valves, alternator and interconnecting electrical harnesses. In some installations the system may include hardware and/or software propeller or reverser functions; in others it may include ignition elements and other control system components common to reciprocating engines.

h. Fault Exposure Time and Average Fault Exposure Time.

(1) When a Minimum Equipment List (MEL) Maintenance Approach is used, the time of occurrence of the fault is known (generally there is a flight deck indication of the failure condition). The fault exposure time is the time that the fault remains present in the system before it is repaired.

(2) When the Periodic Inspection/Repair Maintenance Approach is used, the time of occurrence of the fault may not be known. The average fault exposure time when the fault is found during a periodic inspection is one-half of the periodic inspection interval, since the fault could have occurred at any time during the interval. This assumes that the fault rate of occurrence is constant throughout the interval. If the fault rate is not constant throughout the interval, the average exposure time should be adjusted accordingly.

i. Fleet-Wide Average Loss-of-Thrust-Control (LOTC) Rate. This rate is the "time weighted LOTC rate" of the FADEC system in all modes of operation and dispatch configurations. When in-service data is available, the fleet-wide average is the total number of LOTC events of a family of FADEC systems divided by the total number of flight hours for the FADEC family.

j. Hours. In this document, hours are engine flight hours.

k. In-Flight Shutdown (IFSD). An IFSD occurs when an engine ceases to function in flight and is shutdown. The shutdown could be self-induced, initiated by the crew, or caused by other external influences. An IFSD caused by the FADEC system is considered an LOTC event.

l. Loss-of-Thrust-Control (LOTC). The LOTC is the loss of ability to modulate power or thrust from flight idle to 90% maximum power or thrust. This is the definition used for part 25, 27, and 29 applications. The FAA is developing different definitions for other applications.

m. LOTC Rolling Average. The rolling average is the sum of LOTC events for a given period divided by the in-service hours for the same period; a three month period gives a three month rolling average.

n. Maintenance Interval. In this document, this is a scheduled maintenance interval such as a repetitive periodic maintenance action or an aircraft maintenance letter check (for example, "A" check).

o. Mature Level System. A FADEC system reaches maturity as defined in this policy after 250,000 hours of in-service operation in the particular installation or its equivalent. In addition, to qualify as a mature system data must be provided to demonstrate that the FADEC system has achieved a stable in-service LOTC rate that is consistent with the analysis on which TLD approval is based.

p. Maximum Allowed Fault Exposure Time and Maximum Allowed Average Fault Exposure Time. The maximum allowed fault exposure time limitations in this policy apply to the following situations:

(1) When the time of occurrence of the fault is known, a suitable generic flight deck display of the condition is provided, and the fault category is addressed using the MEL Maintenance Approach; and

(2) When the time of occurrence of the fault may not be known, and the fault category is addressed using the Periodic Inspection/Repair Maintenance Approach.

q. Redundant. This term refers to an alternate, backup, or equivalent method for providing a parameter or function so that the parameter or function can be provided even though one source of the parameter or function is lost or unavailable.

r. Uncovered Fault. An uncovered fault is a faulted parameter or function of the FADEC system that cannot be provided by another means because either the fault is not detected or the fault is detected but no accommodation means is provided.

6. BACKGROUND. This background section is based on part 33 certificated engines installed on aircraft operating under part 121 regulations. Initial FADEC system reliability analyses were essentially based on full-up system configurations; these analyses provided little information in the area of system integrity with faults present. As a result, dispatch criteria for the early FADEC systems entering revenue service was determined by the selection criteria used when establishing the aircraft's Master Minimum Equipment List (MMEL). This criteria follows the traditional path of considering the consequences of the next failure. Due to the complexity of FADEC systems, it was difficult to consider the various failure combinations and the consequences of the next failure. There was little or no supporting safety analysis or field experience on which to base a dispatch decision. This resulted in a somewhat limited dispatch criteria that, in some cases, had a more negative impact on the aircraft delay and cancellation performance than might result from an analysis performed according to this policy.

Aircraft and engine manufacturers recognized that the redundancy features and reliability of the FADEC systems could provide a means for improving (that is, reducing) aircraft delay and cancellation events by enabling redundant systems to dispatch with faults present. The FADEC systems would also improve control system reliability compared to the technology they replace. The dispatch configurations would have to meet engine and aircraft airworthiness standards and demonstrate that the use of non-full-up dispatch configurations would be acceptable over a specified dispatch interval. The manufacturers proposed TLD intervals that would enable aircraft to complete their regularly scheduled route structure. The FADEC faults could then be repaired on a normal maintenance schedule for the aircraft. This work resulted in the original TLD policy, issued by the FAA Engine and Propeller Directorate (EPD) in October 1993. Since that time, the FAA Engine and Aircraft Certification Offices and the Flight Standards Aircraft Evaluations Groups (AEG) have agreed on a revised approach to TLD approval and operations. The changes associated with this revised approach, which is currently being applied, have prompted this revision to the 1993 TLD policy.

The revised approach to TLD approval is appropriate because the FADEC system is not considered "inoperative" when operating with its various system related faults; the system merely loses some of its redundancy. The following factors suggest that the FADEC system does not readily fit the traditional definition of an inoperative system, as addressed by an aircraft MMEL.

a. A maintenance procedure pertinent to TLD is not required before releasing the aircraft for service (in the case of part 121 operations, this may be referred to as 'dispatch');

b. There is usually no operational impact on crew procedures; and

c. Generally, an aircraft performance penalty does not need to be applied before releasing the aircraft for service (or dispatch, for part 121 operations).

The revised approach to TLD approval transfers the authority for the initial approval of FADEC system TLD operations from FAA Flight Standards to FAA Engine Certification. The FAA Flight Standards organizations, however, are still very much involved. The implementation of the maintenance activities required under TLD is done through the operator's MEL and/or the operator's maintenance plan for the aircraft; both of these activities require FAA Flight Standards approval before implementation. Note: Operators under other regulations, such as part 91 operations, may not have MELs or approved maintenance plans.

In TLD applications prior to the issuance of the original TLD policy, FADEC systems were listed in the aircraft's MMEL; this was driven by the operators. The operators did not want any maintenance tasks that were more frequent than an aircraft "A" check. Initial aircraft "A" checks are generally between 250 and 400 hours. The initial periodic inspection for FADEC system short time faults - for entry level FADEC systems - was set at 150 flight hours or 10 calendar days, whichever occurred first. Since this is a shorter time interval than the aircraft "A" checks, the operators wanted an indication on the flight deck that a short time fault condition was present. The operators used the indication to "start the clock" and schedule the appropriate repair(s). Since the flight crew would see the indication, a means to allow dispatch with the indication present became necessary. Thus, an item to address the indication and allow dispatch with short time FADEC faults present was added to the MMEL. However, as indicated in section 14 of this policy, it is acceptable to NOT have any flight deck indications for FADEC short time or long time faults. If an operator prefers, FADEC system short and long time faults may be addressed using a Periodic Inspection/Repair Maintenance Approach.

When the FAA Engine Type Certificate Holding Office (TCHO) approves a TLD limitation, the time limits relating to TLD operations must be included in the FAA-approved Airworthiness Limitations Section (ALS) of the engine's Instructions for Continued Airworthiness (ICA). At aircraft certification and delivery, the part 121 and 135 operators are required to have an established maintenance plan that shows compliance with the engine ALS items. The FAA Flight Standards (FS) organization is responsible for the review and acceptance of the operator MEL and maintenance program. The FS organizations have generally accepted the FAA-approved TLD limitations for MEL purposes, but they have the option to be more restrictive, if necessary, due to other aircraft or operational considerations. For engines installed on aircraft intended to operate under part 121 or 135 regulations, the engine TC holder and the aircraft manufacturer should coordinate before submitting the FAA-approved TLD limitations to the appropriate FS organizations for inclusion into the aircraft manufacturer's MMEL, recommended maintenance plan, or both, and subsequent inclusion in the operator's specific MEL, maintenance program, or both.

To substantiate the reliability goal for the FADEC system under TLD operations, an analysis, such as a Markov Analysis or fault tree analysis, must be applied to estimate the average reliability of the system during normal and TLD operations. The objective of the reliability analysis is to demonstrate that the time-weighted-average of all allowable dispatch configurations meets the reliability requirements associated with FAA engine certification. Analysis techniques are discussed in section 9 of this policy.

The TLD policy established specific requirements for entry level FADEC system TLD approval. These requirements have essentially not been changed. The FAA revised the short time dispatch interval (time limitation) for entry level applications from "150 flight hours or 10 calendar days, whichever occurs first," to "125 flight hours." This is not a significant change and was prompted by operator request. Since TLD operations are being implemented and becoming a standard for small operators and business aircraft operations, in addition to transport operations, the 10 calendar days requirement is considered overly restrictive. The requirement to achieve 250,000 hours of engine operation to be considered a mature level system still applies. After 250,000 hours of engine operation, the FAA will consider applications for extending the TLD short and long time limitations when field service data supports the request.

7. DISPATCH CRITERIA.

a. Dispatchable Configurations. Each dispatchable configuration must:

(1) Meet the part 33 airworthiness operating requirements;

(2) Have at least one channel operating on its dedicated power source; this channel should be capable of being the channel in control;

(3) Maintain the capability of critical engine protection, if provided by the control, (for example, overspeed protection). For additional information, see section 13.a.(1)(c) of this policy;

(4) Maintain a means to provide necessary signals to identify system faults;

(5) Be supported by a statistical analysis for the proposed dispatch intervals;

(6) Not exceed a computed LOTC rate of 100 events per million hours;

(7) Not have additional single failures in the FADEC system that could prevent continued safe flight and landing of the aircraft; and

(8) Meet all aircraft level requirements, when the aircraft installation is known, such as those relating to engine performance, operability, acceleration, etc., unless compensating operational or maintenance procedures are approved.

b. Fleet-Wide Reliability Requirement. The applicant must show by a suitable analysis that the fleet-wide average reliability criteria or "average LOTC rate," which includes full-up as well as degraded system dispatches and uncovered faults, is less than 10 LOTC events per million flight hours.

c. Environmental Requirements. The applicant must demonstrate by analysis, test, or both that all dispatchable configurations continue to meet the environmental certification levels for the system, including those effects associated with high intensity radiated fields (HIRF) and lightning.

8. **DISCUSSION.** The objective of the TLD approach is to preserve suitable FADEC system integrity while minimizing dispatch delays and cancellations caused by the system. The FADEC system may continue to operate with faults present if the resulting system operation and reliability are adequate and operating exposure in this degraded state is appropriately time limited. The applicant must submit a TLD analysis that substantiates the reliability of the proposed allowable faulted configurations for the associated dispatch intervals. The TLD analysis report must define the dispatchable configurations in terms of the faults, usual degraded redundancy, and the associated dispatch intervals.

The following is a method for linking the approved TLD time limits and operations to the engine:

a. The engine TCDS must indicate that the engine control system has been approved for TLD operations.

b. For all engines, the FAA approved ALS of the engine ICA must also include the restrictions and time limits associated with TLD operations.

c. The FAA recommends that the TLD restrictions, time limitations, and other related installation requirements be included in the engine Installation Instructions. This is described in section 16 of this policy.

Table 1 shows the TLD documentation required and the appropriate FAA approval organization for each type of documentation.

Table 2 provides an example of the TLD limitations as they might appear in the ALS of the engine ICA. The FAA requires an in-service reporting system because unpredicted factors could invalidate the analysis. This reporting system should compare service experience of component failures with the modes, effects, rates, and exposure times predicted in the statistical analysis. In addition, this reporting system is used to support future applications for changing dispatch time intervals. Section 18 of this policy provides details of the reporting requirements.

While developing this TLD policy, the FAA has taken into consideration certain aircraft level certification requirements that are significant for this subject. However, the appropriate FAA Aircraft Certification Office (ACO) will make the final determination of the aircraft certification issues. This policy is not intended to prevent the ACO or FS organizations from determining that more restrictive TLD requirements are warranted. Furthermore, any TLD limitation incompatible with aircraft certification or operational approvals will be resolved within the FAA. The FAA may require an amendment to the engine design, ALS, and Installation Instructions, as necessary, to resolve the situation.

9. **SYSTEM MODELS.** The FAA must approve the FADEC system model used in the statistical TLD analysis.

a. Components of the FADEC System. The FADEC system includes, but is not limited to, the EEC, fuel metering unit (hydromechanical control), sensors (including the throttle or power lever sensor elements), actuators, valves, alternator and interconnecting electrical harnesses. In some installations, the system may include propeller or reverse functions; in others it may include ignition elements and other control system components common to reciprocating engines. The fuel pump is considered part of the fuel system and does not need to be included.

It should be noted that, in keeping with the EPD objective that the engine should be independent from the aircraft, LOTC credit should generally not be taken in the system model for the use of aircraft power as a backup power source, unless the FADEC system has been designed to accommodate the interrupts and power transients that can occur in those systems. For example, if aircraft power interrupts associated with bus transfers between the battery source and other generated power sources would cause the FADEC system to shut down the engine, LOTC credit for the use of aircraft power as a backup power source should not be taken. If, however, the FADEC system can successfully operate through all expected aircraft bus transfers and transients within the aircraft's electrical power quality specification, then LOTC credit for use of aircraft power as a backup power source can be taken. When credit is taken for aircraft backup power, the assumed aircraft electrical power quality should be included as an installation limitation in the engine's Installation Instructions.

Data provided from the aircraft may be used as a means to provide fault detection and isolation coverage. If failure or malfunction of aircraft data signals can lead or contribute to LOTC events, the engine's Installation Instructions must state the assumed reliability for that data, and the engine's LOTC analysis must include the failure effects of that data loss or malfunction.

b. Control System Fault Models. The following discussion on modeling the control assumes that the system is a conventional type FADEC system (that is, a dual channel system in which both electronic channels are essentially the same). In the TLD statistical analysis, the applicants have used both full-up and single-fault models to establish the maximum dispatch intervals allowed for the various control system faults. Section 14 of this policy discusses the concept of fault exposure times and their effect on maintenance strategies. The Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5107, Time Limited Dispatch (TLD) Analysis, dated June 1997 provides guidance for performing the TLD analysis.

(1) Full-up Model. A full-up model is one that models all control system states from full-up to LOTC. The model starts in the full-up state, generally called the 0^{th} state, at time zero, and as time progresses, predicts the transfer of the system through the various fault condition states to the LOTC state. These models represent fault conditions to at least the first fault level. When only the first fault conditions are modeled, the model shows only those second fault conditions that cause the system to transition from a first fault condition state to the LOTC state. More complex models show a second fault condition level. These models show the relevant second fault conditions that cause the system to transition from a single fault condition state to the LOTC state, as well as all of the relevant third fault conditions that cause the model to transition from a second fault condition state to the LOTC state. A second fault condition level model is much more complex than a single fault level model. If there are "n" first fault states, there are approximately n(n-1) second fault condition states. Therefore, the number of possible states increases considerably when modeling second fault condition states. It is generally accepted that the modeling of second fault condition states has a small effect on improving the accuracy of the answer of interest, which is the predicted average LOTC rate. This is because the probability of two fault conditions occurring in the system in a given time period is much greater than the probability of three or more fault conditions occurring in that same time period. A conservative assumption for a two fault condition state model is that all third faults lead to an LOTC state. This assumption does not significantly penalize the resultant calculation. For that reason the system's LOTC rate consists primarily of the combinations of two fault conditions that lead to LOTC events, and not the combinations of three or more faults that lead to LOTC events. Adding the second fault state generally increases the accuracy of the predicted LOTC rate by less than 5%; therefore it is acceptable to complete the analysis using a single fault level model. When doing this, the applicant should provide an analysis to show that the modeling of second fault conditions (fault states in which two fault conditions exist together without resulting in an LOTC event) has a small effect (less than 5%) on the predicted LOTC rate. Repair actions can be modeled. The repair actions for given faults or fault categories should be modeled to occur at specified time intervals. Depending on whether the model is an "open loop" or "closed loop" model, as discussed in SAE ARP 5107, the result of the analysis will be either: (a) the instantaneous LOTC rate of the control system at any given point in time; or (b) the average LOTC rate of the system. If an open loop modeling approach is used, the instantaneous LOTC data can be used to determine the average LOTC rate of the control for the modeled fault repair times. If a closed loop modeling approach is used, the result is the average LOTC rate for the fault repair times contained in the model. In either case, the average LOTC rate increases (as expected) with increasing fault repair times. These models are based on repair scenarios in which the time of occurrence of the fault condition(s) is known. Therefore, the repair times modeled actually represent the maximum lengths of time (exposure time) that fault conditions are allowed to be present in the system (before repair is required) and have the system achieve the predicted LOTC rate.

(2) Single-fault Level Model. A single-fault level model is a FADEC system model in which the individual fault conditions are sequentially assumed to exist in the model at time equal to zero, and only those ensuing fault conditions involving that first fault and leading to LOTC events are modeled. Using this modeling approach, the 0^{th} state is not the full-up state; it is the first (assumed) fault condition. The model would show all of the relevant fault conditions that would cause the system to transition from the assumed first fault state to the LOTC state. If modeled, an "in-between first fault level" would show (as separate states) those combinations of two faults that do not result in LOTC events, and the model would show the relevant third fault conditions that cause the model to transition from the first fault level (a dual fault condition state) to the LOTC state. By themselves, each of the single-fault state models is much simpler than a full-up model. However, since all single-fault states have to be modeled, the total task of assembling and analyzing all of the single-fault models is essentially the same as that of doing a full-up model. The single-fault models yield the LOTC rates of the control system (when it starts with that fault present) versus time, for various "modeled" repair times. The data for all of the single-fault states is then "weighted" by the probability of being in that given fault state, to produce an average LOTC rate for the entire control for a

given (modeled) repair time. As in the full-up model, the repair times are actually based on knowing when the fault occurs. Again, the repair times modeled actually represent the maximum length of time that the fault is allowed to be in the system before repair is required and still have the system achieve the predicted LOTC rate. If only single-fault conditions are modeled (that is, the model does not show combinations of two or more fault conditions that could exist simultaneously without the system being in the LOTC state), the applicant should show by analysis that neglecting these higher level states has a small effect (less than 5%) on the result.

Although the mathematical models are generally based on knowing when a given fault occurred (in-service FADEC systems generally "know" when a fault occurs), the specific time that the faults occur is not required to establish a maintenance plan that allows compliance with the time limitations specified in the ALS of the engine ICA. In this case, compliance with the ALS time limitations can be accomplished using a Periodic Inspection/Repair Maintenance Approach for FADEC system faults; section 14.b. of this policy discusses this approach.

10. **UNCOVERED FAULTS.** In the analysis, all uncovered faults must be assumed to lead to LOTC unless they can be shown not to directly result in an LOTC. The analysis must provide the rationale and substantiation for the failure rates used for uncovered faults in the analysis.

11. **COMPONENT FAILURE RATES.** The failure rates for components used in the analysis should be based upon those listed in a data source accepted by the FAA. When the component failure rate is not listed in an acceptable industry source, the failure rate data used in the analysis should be supported by service experience or other equivalent data. In-service data may be used in place of an acceptable industry source when suitable in-service data is available.

12. **FLEET-WIDE AVERAGE LOTC RATE.** The FAA requires that FADEC systems demonstrate an equivalent or better reliability than the hydromechanical technology of early systems. Based on available in-service data, the FAA, in coordination with industry, determined that the IFSD rate attributable to the hydromechanical controls used on engines intended for part 25 transport aircraft applications was approximately ten events per million hours. Therefore, the FAA requirement has been to demonstrate by analysis that the FADEC system would be chargeable for fewer than or equal to ten LOTC events per million flight hours. The analysis for TLD must demonstrate that the fleet-wide average LOTC rate continues to comply with this requirement. The average LOTC rate is the time weighted average of all allowable dispatch states. The analysis to substantiate compliance with this requirement should be summarized in a graph. The ordinates of the graph should be in terms of fleet-wide average LOTC caused by the FADEC system per million hours versus the dispatch time interval in hours. The ordinate of the graph should be extended to show a dispatch time interval of at least twice the length of time of the long time repair interval being requested. Data should be shown for both the short time repair interval being requested and twice the length of the short time repair interval being requested. An example of such a graph is shown in Figure 1. A system may be designed to have only one fault group for TLD dispatchable faults. In this case there would only be one data line. An example of this is shown by the ST=LT line in Figure 1.

13. **DISPATCH INTERVALS.** The applicant must submit a TLD analysis that substantiates compliance with this policy for the desired dispatch configurations and dispatch intervals for the four categories, as applicable, defined in this section. These four dispatch categories are classified as follows:

- No Dispatch
- Short Time Dispatch
- Long Time Dispatch
- Manufacturer/Operator Defined Dispatch

a. Category Definitions.

(1) No Dispatch. No dispatch configurations are those in which the FADEC system has a fault or faults that result in any of the following:

(a) The performance and operation of the engine does not meet its approved type design, which has been shown to comply with part 33 requirements;

(b) The system has suffered a complete loss of a critical resource or a critical function;

(c) The system does not have engine overspeed* or a critical limit protection function* (applicable when the control system is providing such a function); or

(d) The computed LOTC rate of the system (with the fault(s) present) is greater than 100 events per million hours.

*Note: Exhaust Gas Temperature/Inter Turbine Temperature (EGT/ITT) is not considered a critical limit protection function, even though some engine control systems are configured to provide that function. The EGT/ITT display is considered sufficient for indication of an over-temperature condition. In addition, a loss of rotor over-speed protection may not be of major concern in some rotorcraft operations. In practical applications, such as rescue operations or evacuations from distressed areas, the lack of turbine overspeed protection may be a lesser concern. In these installations it may be better to have a separate cockpit indication for loss of the protective function and save the no dispatch indication for conditions in which the control does not have the resources to provide minimally acceptable engine operation. The phrase "minimally acceptable" will always generate discussion. The simple question to be answered, in some scenarios, is if there is a greater risk in staying vs. leaving the area. In difficult situations, the flight crew has to make that decision. In these particular applications, the failure conditions that initiate a no dispatch indication should be carefully reviewed and minimized as necessary.

(2) Short Time Dispatch. Short time dispatch configurations are defined by all of the following:

(a) The system has a fault or faults that do not fall into the no dispatch category;

(b) A fault or faults that cause a significant loss of FADEC system signal redundancy, such as loss of a channel CPU; and

(c) The computed LOTC occurrence rate with the fault(s) present is less than 100 events per million hours but greater than 75 events per million hours.

(3) Long Time Dispatch. Long time dispatch configurations are defined by all of the following:

(a) The system has a fault or faults that do not fall into the no dispatch or short time dispatch categories; and

(b) The computed LOTC rate is less than 75 events per million hours.

(4) Manufacturer/Operator Defined Dispatch. This category is for faults that do not fall into any of the other three categories (no dispatch, short time dispatch, and long time dispatch), and do not have an impact on the LOTC rate. These faults do not have to be included in the LOTC analysis; however, they should be included in the TLD report, and it should be substantiated that these fault conditions do not have

an impact on the LOTC rate. The repair interval for these faults may be agreed upon between the engine and aircraft manufacturers, the operators, or both.

b. Statistical Analysis Results. Table 3 illustrates the allowed dispatch intervals. The dispatch intervals for entry level and mature level FADEC systems have been separated to consider factors not included in the statistical analysis. The statistical analysis is based largely on electronic component databases that consider components to be mature. Because the components are assumed to be mature, only random failures are considered in these databases. Failures due to design, manufacturing and quality are not included in the database.

Because system faults attributable to design, manufacturing, quality and maintenance errors are not covered by the statistical analysis, this document introduces a factor related to service experience (see section 13.c. of this policy). The experience factor provides a safety margin for faults in the fleet resulting from latent design, manufacture and quality deficiencies and maintenance errors, because these faults tend to be exposed and corrected as in-service time is accumulated. This safety margin is addressed by providing more conservative criteria for dispatch intervals for entry level systems compared to mature level systems, even though the statistical analysis may support dispatch for a longer dispatch interval for entry level systems.

c. Margins. The predicted fleet-wide average LOTC rate analysis should comply with the fleet-wide average LOTC rate criteria at a time equal to two times the long time dispatch interval for which the applicant requests approval. The predicted LOTC rate, considering full-up as well as all allowable dispatch conditions, should be equal to or less than 10 events per million hours, assuming short and long time exposure intervals that are twice as long as those being requested. The FAA provides this 2:1 margin to cover uncertainties in the analysis.

d. Entry Level Systems. A FADEC system is classified as an entry level system if it has less than 250,000 flight hours of field experience. The applicant may request alleviation from this classification if it has sufficiently similar systems operating in the field that have accumulated greater than 250,000 flight hours. The FAA will review such an application on a case-by-case basis. Table 3 gives the maximum exposure time limitations for the short and long time fault categories for entry level systems.

e. Mature Level Systems. For mature level systems, the FAA engine TCHO approves the short and long time dispatch intervals on a case-by-case basis, depending upon the system, analysis, and service experience. After a FADEC system has accumulated 250,000 flight hours in-service operation, an applicant may request a change in FADEC system status from entry level to mature. The applicant must provide data to support this change. The data must demonstrate that the FADEC system has achieved a stable in-service LOTC rate that is consistent with the analysis on which TLD approval is based. Derivatives of similar FADEC systems can be considered to be part of a FADEC family. If the engine TCHO approves, the summation of a family of FADEC systems in-service flight operation times can be used in the maturity evaluation.

f. Substantiation Data for Dispatch Levels. The applicant must submit the TLD statistical analysis report to the FAA engine TCHO. The report must include a tabulation of the various proposed dispatch configurations that provides: (1) the expected frequency of occurrence of the faults leading to those dispatchable configurations; and (2) the LOTC rate of the system when operating in those configurations. The report must tabulate the chosen category for each fault covered in the analysis and show that the exposure time chosen for the short and long time fault categories allows the control system to meet its reliability requirements. The analysis should substantiate that faults classified in the new fourth category, manufacturer/operator defined faults, do not impact the LOTC analysis. The analysis must also provide a substantiation or justification, including failure rates, exposure times, and other assumptions, for fault(s) that impact engine operability, reliability, or durability.

Based on a positive review of the analysis and data provided in the report and discussions with the applicant, as required, the TCHO may grant approval for the requested TLD. The FAA-approved ALS of the engine ICA must include the TLD approval information.

14. **MAINTENANCE STRATEGIES.** Applicants have proposed the use of two different maintenance strategies to implement the TLD time limitations. Either strategy or a combination of both may be used; one may be used for the short time faults, and the same or different strategy may be used for the long time faults. In either case, the approved dispatch interval must be substantiated by a TLD statistical analysis that uses a full-up model, a single-fault system model, or the equivalent. Section 9 of this policy discusses system models. This section discusses the differences in TLD maintenance activities when applying these strategies.

a. No Dispatch. Regardless of the maintenance strategy, there will be non-dispatchable configurations. The presence of a no dispatch fault condition must be indicated in the flight deck by essential equipment. Essential equipment is equipment available for every aircraft dispatch.

b. MEL Maintenance Approach. When using this maintenance strategy, the fault occurrence time is known because there is a generic flight deck indication of the condition, and the fault must be repaired before the end of the approved interval. For this strategy, the fault exposure time is the time from when the fault occurred to when it is repaired. For example, if the fault condition is indicated and the fault is not repaired until 100 hours after its occurrence, the entire 100 hour period is the fault exposure time. The short time fault category is generally handled using this approach; however, this is not a requirement. Short time faults could be addressed with a Periodic Inspection/Repair Maintenance Approach. When using the MEL Maintenance Approach, the presence of a fault condition in this category is generally indicated in the flight deck on essential equipment so that the flight crew and/or maintenance personnel can "start the clock" when the fault condition first occurs. This is called the MEL Maintenance Approach because the flight deck indication is generally apparent to the flight crew; therefore, an MEL entry is needed to allow dispatch with the fault indication present. Many applications using this approach "start the clock" at midnight on the day the fault indication occurred; this practice has been reviewed with Flight Standards and is acceptable.

When an MEL Maintenance Approach is used, the item should be listed in the aircraft's MMEL. An operator reflects that item in its MEL. The MEL Maintenance Approach is generally used for fault conditions that require repair within a relatively short time period, such as 125 flight hours, although longer time periods, such as 300 flight hours, have been approved. This approach is not normally used for fault categories in which the allowed dispatch interval is greater than 300 flight hours. Flight crews must disposition all MEL items before every dispatch because dispositioning a given MEL item of more than 300 flight hours is burdensome.

Note: When using the MEL Maintenance Approach, the aircraft's MMEL may not list the specific time period associated with a given fault category. Instead, the MMEL may reference the ALS of the engine ICA or an engine manufacturer's document that contains the FAA-approved time limitations. The operator's MEL, however, should show the specific time period of allowable dispatch. The flight crews need to know the allowable dispatch times; a reference to a document that is not readily available is not useful.

The aircraft MMEL is developed by the Flight Operations Evaluations Board (FOEB) for a given type design aircraft. An FAA FS Operations Inspector from the AEG assigned to the aircraft serves as chairperson of this board. The board is usually made up of FAA airworthiness inspectors for maintenance and operations and an assigned flight test pilot. The FOEB accepts input from FAA engineering, the aircraft and engine manufacturers, as well as the operators. Evidence of TLD approval by the part 33 TCHO and the listing of the time limitations in the ALS of the engine's ICA, combined with the appropriate generic flight deck indication, is usually sufficient to substantiate the acceptability of the desired MMEL listing. However, the FOEB can be more restrictive if they consider it necessary.

Though unlikely in a reliable system, it is possible for more than one short time fault to occur in a system during a short time interval. An example of a first short time fault might be the loss of one channel's dedicated power supply. The "clock" would be started for this fault condition. If the channel does not have a back-up power source, the remaining channel would have to sense the channel loss and report the fault condition. Although it is unlikely, a second failure that could occur is a failure in the affected channel's CPU. The exact cause of the first short time fault condition (in this example, the loss of one channel's power supply) may or may not be known because a generic indication is usually displayed in the cockpit to indicate the presence of a fault in this category, rather than an indication that identifies the specific fault. But, the "exposure clock" must be started when the first fault occurs. Maintenance personnel will find the existence of the second short time fault before or during the repair of the first fault. If the date of the second fault can be adequately determined by using a system that has been developed and certified to the appropriate software development assurance level (see section 16 of this policy), the MEL "clock" for the second fault can be back-calculated, and the second fault condition may not have to be repaired when the first fault condition is repaired. The second fault can have its own time period. However, if there is no suitable (acceptable to the FAA) media to indicate when the second fault occurred, all short time faults must be corrected at the time of the first fault repair. In the above example, if there is no suitable media for determining when the second short time fault (CPU failure) occurred, both faults (the power supply and the EEC unit, which contains the CPU) must be repaired within the time interval established by the first fault (power supply fault).

c. <u>Periodic Inspection/Repair Maintenance Approach</u>. This maintenance approach applies a periodic inspection and repair strategy to manage FADEC system faults. The approach is generally used for FADEC system faults allowed to remain for time periods greater than 300 flight hours before requiring repair. This approach is normally only applied to long time faults, but it has been applied to short time faults if a generic flight deck indication is not available for the presence of a short time fault condition. When using this approach, the time at which the fault first occurs does not have to be known. The FADEC system must be interrogated by maintenance for the presence of faults during periodic inspections, and the faults found must be repaired within a specified time period or interval, so that the average exposure time of a fault in a particular category does not exceed the maximum average allowed exposure time for that category. The average exposure time of the system to a fault is simply the average length of time that a fault is present in the system before it is repaired.

The following assumption should be used when applying this strategy. If a fault is found during a periodic inspection, the fault could have occurred at any time throughout the interval; therefore, assume that the fault occurred, on average, half-way through the interval. This assumption is acceptable when the failure rates for the faults in a particular category are essentially constant with time, and the periodic inspection interval (in hours) is less than the mean time between failures (MTBF) of the sum of the failure rates of that particular fault category. If either of these conditions is not true, the periodic inspection/repair interval should be adjusted accordingly.

Consider the following example:

> A Periodic Inspection/Repair Maintenance Approach is being applied to long time faults, and the limitation relating to those faults is that they must be repaired within a time period sufficient to ensure that the maximum average exposure time of the system to the long time fault does not exceed 250 flight hours. With this information, an operator might arbitrarily establish a task to periodically

inspect for long time faults every 400 flight hours. If faults are present when the system is inspected, the applicant can assume that those faults occurred half-way through the interval and are on average 200 flight hours old. If the maximum average exposure time of the system to these faults must be limited to 250 hours, then faults found during the 400 hour periodic inspection must be repaired within 50 flight hours to meet the maximum average exposure requirement.

With this approach, the time limitation in the ALS could be met using an inspection period that is twice as large as the maximum allowable exposure time limitation given in the ALS for those faults. This is shown in Table 4; the right columns of the two columns under the "Short Time Faults" and "Long Time Faults" give the maximum periodic inspection/repair interval. However, if the maximum inspection/repair time is chosen, there would be no time to schedule the repairs of those faults to a future date because the faults found, on average, would be at the maximum average allowable exposure time limit. The faults found would have to be repaired before the aircraft could be returned to service. This is why the operators would normally interrogate the system at a periodic interval that is less than the maximum inspection/repair time.

In the above example, the time limitation for the maximum allowed average exposure time to faults was assumed to be 250 flight hours. A maximum inspection/repair time of 500 hours could be used for the inspection/repair interval, but if a 500 hour interval is used, all faults found at that inspection would have to be repaired before the aircraft could be returned to service. By doing the inspection at a shorter interval (400 hours), any faults found would be on average 200 hours old, and the faults would not have to be repaired immediately. An additional 50 flight hours of operation could be allowed before the repair of those faults is required. This example results in a total inspection/repair time of 400 hours for the inspection and 50 hours for the repair, or 450 hours. This reduces the maximum inspection/repair time of 500 hours by 50 hours, but is more flexible because faults found do not have to be repaired immediately; the repair can be scheduled to a more convenient time.

In summary, when using the Periodic Inspection/Repair Maintenance Approach, inspecting at a periodic interval less than the maximum inspection/repair time allows the repair actions for faults to be deferred to an appropriate future date. If the repair of those fault(s) found at inspection is deferred, the faults' average exposure time would consist of half of the inspection interval (in hours) PLUS the operating time between the inspection and when the fault(s) are repaired. The repair actions must be scheduled so that the faults do not exceed their maximum allowed average exposure time limit.

Maintenance personnel usually defer faults found during an inspection by completing a Non-Routine Maintenance/Inspection Card after the inspection. All faults in the category being inspected should be listed on the card in the "DISCREPANCY" field. The following may be used in the "ACTION TAKEN" field: "Deferred in accordance with the Airworthiness Limitations Section of the engine's ICA, chapter xx, page xx, date xx. Repairs to be completed by calendar date "xxx." The planned date of repair, "xxx," should not cause the faults to remain in the system longer than the maximum average allowed exposure time."

It should be noted that dispatch with these faults is not part of an operator's MEL system. These faults are addressed as part of the operator's scheduled maintenance program; an MEL entry for faults being handled in this manner is not necessary.

If the repair of faults is deferred, maintenance personnel may find new faults during the repair that would not have been recorded on the last inspection's Non-Routine Maintenance/Inspection Card. If the date of these new faults can be "acceptably" determined, their repair can be deferred to a future date by completing a new Non-Routine Maintenance/Inspection Card. (See the discussion on "Impact of Software Integrity of the Maintenance Computer or Display Media on the Periodic Inspection/Repair Maintenance Approach" in section 16.c. of this policy.) If the date of the newly found faults cannot be "acceptably" established, all faults in the subject category must be repaired by the date established at the previous inspection.

d. Faults Found During Non-FADEC System Scheduled Inspections. Invariably, FADEC system fault conditions are found during other maintenance inspections of the aircraft or engine. How should these faults be addressed? The recording of these faults is required; maintenance personnel must complete a Non-Routine Maintenance/Inspection Card for the faults found. This card enters the faults into the operator's maintenance program system.

The following scenario may occur in service: A short time fault category is being handled using the MEL Maintenance Approach or the Periodic Inspection/Repair Maintenance Approach. Upon inspecting the aircraft's maintenance system as part of a short time fault related task (or other engine related maintenance activity) maintenance personnel find the presence of a fault in the long time category. The FAA recommends that the maintenance personnel complete a Non-Routine Maintenance/Inspection Card for all fault(s) found. The "ACTION TAKEN" field on the card should indicate that the long time fault would be repaired as if it had been found at the next periodic inspection for this category. If, when using the Periodic Inspection/Repair Maintenance Approach, a fault is found during other engine related maintenance activity, the card should indicate that the fault would be repaired as if it had been found at the next periodic inspection for this category.

e. Examples of Operator Approaches to FADEC System, TLD Related Maintenance. In-service applications of TLD have used these maintenance approaches individually and in combinations. The following examples are approaches used in service:

(1) Some operators want all FADEC TLD faults except the manufacturer/operator defined dispatch faults to be placed in the short time category; they use an MEL item to allow dispatch with those faults present (for the approved time period). They have a flight deck indication associated with the presence of a fault condition. The flight deck indication is usually a generic indication, such as a light or message that indicates short time fault(s) are present. If a previous fault in that category is still in existence, successive faults do not generate a "new" indication.

(2) Some operators use a combination of the two approaches. They have an MEL listing for short time faults (with an associated generic flight deck indication of the presence of a short time fault), and they use a periodic inspection/repair task for long time faults. The long time faults do not have an associated flight deck indication.

(3) Some operators use two separate periodic inspection/repair tasks to address the short and long time TLD faults. These applications have no flight deck indication associated with the presence of either a short or long time fault condition.

Whatever approach is used, the time limits associated with short and long time operations must be integrated into the ICA for the aircraft. Appendix H of part 25 requires that engine Airworthiness Limitations be included as part of the aircraft ALS. Both Appendix A to part 33 and Appendix H to part 25 require that the FAA approve the ALS and specify required maintenance under §§43.16, 25.1529, and 91.403, unless the FAA has approved an "alternative" program. As shown in Table 2, which lists the time limitations associated with short and long time fault categories, the following note should be included with the ALS entries relating to TLD: "The time limitations specified above may only be changed with approval of the FAA engine Type Certificate Holding Office."

f. Engine TLD Limitations Associated with the MEL and Periodic Inspection/Repair Maintenance Approaches. The engine TLD limitations for short time and long time faults, shown in Table 3, are given in terms of the maximum exposure times for those faults. Table 4 shows this data for the MEL Maintenance Approach or the Periodic Inspection/Repair Maintenance Approach.

g. Extension of Long Time Dispatch Interval. If indicated in the FAA-approved ALS of the engine ICA, the FAA Principal Maintenance or Avionics Inspector (PMI/PAI) may authorize a temporary extension of the long time dispatch interval of up to ten percent of the interval, not to exceed fifty hours, to avoid an aircraft-on-ground (AOG) situation. An example of such an unexpected situation is if the aircraft is diverted because of weather and a revenue flight cannot be made back to the maintenance base because time has run out on the long time dispatch interval. This extension is intended to cover unexpected situations, not to routinely extend the approved interval.

15. **SYSTEM REPAIR**. When two long time faults combine to yield a short time dispatch category, one of the faults can be repaired, resulting in an upgrade to a long time dispatch category. This flexibility is not intended to relieve the operator from repairing the remaining FADEC fault within the approved interval for long time faults. Similarly, when two short time faults combine to yield a no-dispatch condition, one of the faults may be repaired as long as the remaining short time fault is repaired within the approved short time fault interval.

16. **ENGINE -** AIRCRAFT INTERFACE. The FADEC system is required to supply fault status and dispatch information to the aircraft. This data must satisfy both engine and aircraft dispatch policies. This policy defines the dispatchable configurations and associated dispatch intervals at an engine level. These configurations and criteria are in accordance with the certification basis for the engine. However, this engine dispatch policy does not prevent the ACO from imposing more restrictive aircraft dispatch criteria if necessary.

a. FADEC System Software Changes Affecting TLD Operations. The TLD fault status and dispatch information is part of the engine ALS. The engine TCHO must review and approve proposed changes to TLD limitations. Changes to the FADEC system software that affect TLD operations must be coordinated as follows:

Changing the fault classifications by adding faults or modifying a given fault category should be done in conjunction with software updates to the EEC. The engine TCHO must review and approve these changes as part of the requirements validation in the software process. TCHO approval and incorporation of the software change constitutes approval of the TLD fault classification change. Changes in fault classification may or may not require changes to the ALS; however, they will always require a change to the engine manufacturer's TLD report if the approved TLD report does not support the classification in a less restrictive dispatch category. The engine manufacturer should coordinate changes to the TLD basis with the aircraft manufacturer. The aircraft manufacturer should coordinate the changes with the responsible ACO.

When an engine manufacturer obtains TLD approval for the engine's FADEC system, the FAA recommends that the manufacturer modify the engine's Installation Instructions to include the following information:

(1) FADEC system fault information relating to TLD;

(2) Time limits associated with the various, dispatch allowed, fault categories. The time limits information should indicate if the engine manufacturer assumes a given fault maintenance strategy (MEL Maintenance Approach or Periodic Inspection/Repair Maintenance Approach). The time limits information could also be provided in a manner that allows the installer (and operator) to choose either the MEL or Periodic Inspection/Repair Approach to address FADEC system short time and long time fault maintenance; and

(3) The certification of and a reference to the associated maintenance requirements relating to engine, aircraft or ground support equipment used to store and display fault information and/or FADEC system messages related to TLD operations. Section 16.c. of this policy provides information on associated maintenance requirements.

If information relating to TLD fault categories and time limits is included in documents other than the Installation Instructions, the Installation Instructions should reference those documents.

The FAA also recommends that the engine manufacturer reference the FAA Transport Aircraft Directorate Part 25 Policy Letter, TAD-95-001, dated February 22, 1995, in the engine Installation Instructions or other appropriate documents. The policy discusses the use of an aircraft central maintenance computer (CMC) as the sole means of completing FADEC system maintenance and the certification requirements applying to such a system.

The engine manufacturer may not know the specific applications for the engine at the time of engine certification. Therefore, the engine Installation Instructions should recommend a meeting between the engine and aircraft certification authorities, the AEG, and the engine and aircraft manufacturers. This meeting would be held when the installer chooses the engine and the engine is approved for TLD operations. The meeting would determine if the aircraft manufacturer's approach for complying with this TLD policy is acceptable.

b. Software for FADEC System Fault Messages and Displays.

(1) FADEC system "no dispatch" indications must be provided in the aircraft's flight deck by equipment available for every dispatch. If that display equipment involves the use of software, that software must have a development assurance level equivalent to DO-178B, level A if subsequent operation of the aircraft could lead directly to a catastrophe, or level B otherwise.

(2) When the MEL Maintenance Approach is used for either short time or long time faults, the flight deck display system used to show that the FADEC system has those faults present (for which MEL relief is provided) must be provided on essential equipment. If that equipment involves the use of software, the software must have a development assurance level equivalent to DO-178B, level C.

(3) If a generic message is displayed by an aircraft avionics system, or other media involving the use of software, to show that the FADEC system has either short time or long time faults present, and that category (one or both) is being addressed with a Periodic Inspection/Repair Maintenance Approach, then that generic message must be displayed on essential equipment. If that equipment involves the use of software, the software must have a development assurance level equivalent to DO-178B, level C. (This does not necessarily apply to detailed fault information, discussed in paragraph c. of this section.)

c. Impact of Software Integrity on the Periodic Inspection/Repair Maintenance Approach. When using the Periodic Inspection/Repair Maintenance Approach, engine and aircraft manufacturers and operators have had many questions about the media used to store and/or display information concerning FADEC system faults and how to use that information. These questions focus on the software assurance level used for the aircraft's CMC or other device that stores and/or displays a generic FADEC system fault message and the associated FADEC system fault information.

When using the MEL Maintenance Approach, the flight deck indication (a generic message or light indicating that there is a fault in a particular category) is usually provided by a media with a satisfactory level of software development. When the indicator is a light, software is usually not involved.

FAA Policy Letter TAD-95-001 requires that the media used to store and display maintenance information for critical systems, such as FADEC systems, must have a software assurance level equivalent to DO-178B, level C. Software designers indicate that this could have a significant cost impact on developing many of the current complex CMC systems. Due to this, some applicants have pursued the approach of FADEC systems reporting a generic "long time (and short time, if applicable) fault present" message(s). The details of the particular fault(s) could be reported by a media such as a dumb display (a display not driven by software). This display may be either connected directly to the FADEC system data buses or it may utilize a "hand shake" with the FADEC system that ensures the integrity of the displayed information. However, if the media that displays the generic message uses software, that software must have adequate software integrity. If this requirement is not met, the FADEC system could report faults, and the maintenance personnel could inspect for faults, but the faults may never be found because the device that stores and displays that information does not have adequate software integrity. Therefore, the FAA recommends that the engine manufacturer include this requirement for adequate software integrity in the engine Installation Instructions.

d. Detailed Fault Information. Maintenance personnel need detailed information about the particular fault(s) present to perform repairs. The following example illustrates the difference between systems that do and do not have adequate software integrity:

Example:

> A TLD time limit for the average exposure of the FADEC system to faults in a particular category is 300 flight hours. A periodic inspection at 200 hours is used to find the faults. If faults are found, they are on average 100 flight hours old. Maintenance personnel then schedule their repair within the next 200 flight hours at the next inspection/repair interval. At the time of the repair they confirm that the repair was completed. When confirming the repair, maintenance personnel could find a "new" fault in the particular category being worked. Does this new fault have to be repaired immediately, or can the repair be deferred until the next periodic inspection/repair activity?

(1) When the system that stores and displays the details of the particular faults causing the generic fault indication or message has adequate software integrity, the new fault does not have to be repaired immediately. Repair of the new fault can be deferred until the next periodic inspection/repair activity. This allows inspections and repairs to be completed on a continuous cycle. Faults found at the last inspection/repair activity are repaired during the next periodic inspection/repair activity; any new faults found can be scheduled for repair during the subsequent periodic inspection/repair activity.

Using this approach, if the inspection/repair interval is equal to or less than 2/3 of the maximum allowed average exposure time limit, the average length of time that a fault would be present in the system before repair would be equal to or less than the maximum allowed average exposure time specified for those faults. In this scenario, the system never has to be "cleared" of all faults in a particular category at a particular time. There could always be a fault in the system, and it would be acceptable.

(2) A concern arises when the system that stores and displays the details of particular faults that cause the generic fault indication or message does not have adequate software integrity. In this situation, the maintenance reporting system may not be storing and/or displaying one or more faults in a particular category; those faults could be present in the system, and maintenance personnel would not be aware that there are faults needing repair. In this case, maintenance personnel can still use an overlapping inspection/repair approach, but another requirement is added.

Maintenance personnel must bring the system full-up with respect to all faults in a particular category, at an interval that does not exceed twice the maximum allowed average exposure time for those category faults. This can be done, even though the maintenance reporting system(s) for the fault details may not record and/or display some detailed fault information properly, because the media used to display a generic message for a fault in a particular category is an essential display and has adequate software integrity. This is the reason that a generic indication or message must be displayed on essential equipment. If there is a generic message for a fault category and the aircraft maintenance system does not have details of the fault condition(s), maintenance personnel will start changing components to eliminate the generic fault message. The instructions in the engine maintenance manual (and, if appropriate, the aircraft maintenance manual) must indicate that the aircraft cannot be returned to service until the FADEC system faults causing the generic fault message are repaired, and the generic indication or fault message is no longer displayed.

e. In-Flight Faults. Some faults or fault conditions may only occur in-flight. If this is the case, the engine maintenance manual instructions should indicate that, regardless of whether these faults are in a category addressed by the MEL Approach or an Inspection/Repair Approach, it is to the operator's advantage to begin the repair of these faults several flight hours before the end of the interval. This will allow several flights to be completed and will allow maintenance to verify that their repair actions have been successful before the end of the approved exposure interval.

Example:

> Using an inspection/repair maintenance approach to address long time (LT) faults, assume that the maximum average exposure time limit is 500 flight hours. In this case the system must be cleared of all LT faults within a time interval that does not exceed 1000 flight hours. To meet this requirement, the operators should begin the inspection and repair of LT faults at a shorter interval, such as 800 flight hours. After repair actions are taken, the system can complete several flights and be re-inspected to ensure that there are no in-flight LT faults present in the system at the 1000 flight hour point.

f. Configuring the FADEC. Figure 2 shows typical aircraft system configurations involving the aircraft's engine indicating and crew alerting system (EICAS), which may or may not include a multi-function display or maintenance page. It also shows a typical CMC system, which may or may not receive FADEC maintenance data. The following information may be helpful for configuring the FADEC when applying the Periodic Inspection/Repair Maintenance Approach.

(1) The display media for indicating the presence of FADEC inspection/repair category faults must have adequate software integrity. (See section 5 of this policy for the definition of "adequate software integrity.")

(2) If a generic type message is shown on a multi-function display or maintenance page of EICAS and the CMC does not have adequate software integrity, the information for the generic message must be transmitted through EICAS (shown as a solid line in Figure 2) or directly from the FADEC EEC units (shown as dashed lines in Figure 2).

(3) If the generic type message is displayed on a laptop, the laptop's processing and/or display of that information must have a software assurance level equivalent to DO 178B, level C. Figure 2 illustrates this as well.

(4) If detailed fault information is displayed on a media, including the data path to that media, that does not have adequate software integrity, the FADEC system must be cleared of all faults in that category without exceeding the maximum allowed average exposure time for those category faults. (This is done by

making the necessary repairs until the generic fault message, which shows that there are still faults present, is no longer displayed. If software is involved in the display of the generic fault message, that software must be developed in a manner equivalent to DO-178B, level C standards.)

(5) If the detailed fault information is displayed on a media, including the data path to that media, that does have adequate software integrity, those new faults found during the periodic inspection/repair maintenance activity do not have to be repaired in this period. They may be repaired at a future date, provided that the average exposure time of all faults does not exceed the approved maximum average exposure time for that group of faults.

17. **REPORTING SYSTEM.**

a. <u>General Reporting Requirements</u>. The applicant must institute a formal, auditable reporting system that will provide periodic reports that will be available to the FAA engine TCHO. The reporting system is a requirement for the TLD approval for the applicant's engine. Failure to maintain the required reporting system could affect the continued approval of TLD. The FAA will use the reported data to assure that the in-service reliability of the FADEC is consistent with the analysis on which the TLD approval is based. The reporting system should also provide the FAA with an early warning of component trend failures. The applicant's TLD performance will be reviewed periodically to determine if the reporting system should be modified. Also, the FAA will determine through the periodic review(s) if corrective action relating to TLD, such as adjusting dispatch intervals, is required.

b. <u>Report Contents</u>. The reports must include the following:

(1) A plot of three and twelve month rolling averages of LOTC events per million hours versus accumulated FADEC system hours.

(2) An assessment of the FADEC reliability versus that predicted by the TLD analysis. The assessment should cover the report period and the entire period since initiation of TLD. The assessment should also consider individual component failure rates and other assumptions used in the statistical analysis, for continued validity.

In addition, the assessment should report any unpredicted component failure modes or effects and any recurring problems with detecting, isolating, and repairing faults within the required interval. Items b.(1) and b.(2) may be simplified when a system reaches maturity and the in-service data has substantiated the accuracy of the system model and the results of the statistical analysis.

c. <u>Problem Reporting</u>. The applicant should inform the FAA engine TCHO, as soon as practicable, of potential in-service airworthiness concerns resulting from design, manufacturing, quality or maintenance errors that may affect FADEC system operation or reliability. This information should be transmitted to the FAA even if LOTC rates are not currently affected. This does not change or affect the obligation of type certificate holders or operators to report in-service problems under the CFR.

d. <u>Reporting System Life</u>. Since the factors of concern are not necessarily time dependent, the reporting system for a given FADEC system will be continued as long as the TLD operations are in use. For mature FADEC systems, the frequency of the reporting may be reduced if approved by the TCHO.

Original signed by JJP on 6/29/01
Jay J. Pardee

Table 1. TLD Approval

	APPROVAL ORGANIZATION/GROUP		
	Engine Certification Office	Flight Standards – Aircraft Evaluation Group (AEG)	Flight Standards – Field Inspectors (Principle Maintenance Inspectors (PMI), Principle Avionics Inspector (PAI), Principle Operations Inspector (POI))
Documentation ====>	ICA and TLD Analysis Report as part of engine certification	MMEL and/or Maintenance Review Board Report entries relating to TLD. (Entries must be compliant with TLD Limitations as given in engine ICAs.)	MEL and/or Operator's Maintenance Plan entries relating to TLD. (Entries must be compliant with TLD limitations as given in engine ICAs.)
Part 121 & 135 Operators	N/A	✓	✓
Part 91 Operators	N/A	N/A **	N/A **

** Compliance with the engine ICAs is an Operator responsibility under Part 91 Operations.

TABLE 2. Typical ALS Entry for TLD Limitations.

<table>
<tr><td colspan="2">TASK 05-xx-xx-xxx
This page block gives the FAA-approved time limits to operate this engine (identify engine manufacturer and model) with control system faults present. These limits are also defined in engine report (identify report number and date), the Engine Control System Time-Limited-Dispatch report.</td></tr>
<tr><td>Fault Category</td><td>Operational Limitation</td></tr>
<tr><td>NO DISPATCH FAULTS</td><td>DISPATCH NOT ALLOWED WITH THIS CONDITION PRESENT.
Note 1: There must be a flight deck display of the presence of a no dispatch condition.</td></tr>
<tr><td>SHORT TIME FAULTS</td><td>DISPATCH IS ALLOWED WITH SHORT TIME FAULTS PRESENT. THE MAXIMUM (AVERAGE – IF APPLICABLE) EXPOSURE TIME OF THE SYSTEM TO THESE FAULTS MUST BE LIMITED TO (insert XXX) FLIGHT HOURS.

Note 2: All faults in this short time category must be corrected within a time period, such that (a) each fault in the group does not have an exposure time greater than (insert XXX) hours, OR (b) the average exposure time for short time faults does not exceed (insert XXX) hours. Also, it is noted that the time limitations contained herein with respect to short time FADEC system faults may only be changed with approval of the FAA engine TCHO.

• If an MEL Maintenance Approach is used for this fault category, there should be an appropriate generic flight deck display of the presence of a short time fault condition(s).

• If a Periodic Inspection/Repair Maintenance Approach is used, the system should be inspected for short time faults at an interval, such that if faults are found, they can be repaired so that the average length of time that a fault is present in the system (average exposure time) does not exceed the specified (insert XXX) hour limitation.</td></tr>
<tr><td>LONG TIME FAULTS</td><td>DISPATCH IS ALLOWED WITH LONG TIME FAULTS PRESENT. THE MAXIMUM (AVERAGE – IF APPLICABLE) EXPOSURE TIME OF THE SYSTEM TO THESE FAULTS MUST BE LIMITED TO (insert YYY) FLIGHT HOURS.

Note 3: All faults in this long time category must be corrected within a time period, such that (a) each fault in the group does not have an exposure time greater than (insert YYY) hours, OR (b) the average exposure time for long time faults does not exceed (insert YYY) hours. Also, it is noted that the time limitations contained herein with respect to long time FADEC system faults may only be changed with approval of the FAA engine TCHO.

• If an MEL Maintenance Approach is used for this fault category, there should be an appropriate generic flight deck display of the presence of a long time fault condition(s).

• If a Periodic Inspection/Repair Maintenance Approach is used, the system should be inspected for long time faults at an interval, such that if faults are found, they can be repaired so that the average length of time that a fault is present in the system (i.e., average exposure time) does not exceed the specified (insert YYY) hour limitation.</td></tr>
<tr><td colspan="2">Note 4: The FAA Principal Maintenance or Avionics Inspector may approve an extension, not to exceed 50 flight hours, to the long time dispatch limitation if repairs cannot be made due to extenuating circumstances.</td></tr>
<tr><td colspan="2">Note 5: The applicant to add the following words here: “THE TIME LIMITATIONS SPECIFIED ABOVE MAY ONLY BE CHANGED WITH THE APPROVAL OF THE FAA ENGINE TYPE CERTIFICATE HOLDING OFFICE.”</td></tr>
</table>

Table 3. Maximum Operating Times for TLD Operations.

Limitations on FADEC System Operations with Faults Present

Experience Level	No Dispatch Category	Short Time Faults Category - maximum operating time	Long Time Faults Category – maximum operating time	FADEC System Faults Not Affecting the LOTC Rate of the Control
Entry Level	No Flights Allowed	125 flt. hrs.	250 flt. hrs.	(2)
Mature Level	No Flights Allowed	(1)	(1)	(2)

(1) Times vary depending upon the system, analysis and service experience.
(2) The time to repair should be included in an appropriate document.

Table 4. Maximum Operating Times for TLD Operations Associated with the "MEL Maintenance Approach" and "Inspection/Repair Maintenance Approach."

Limitations on FADEC System Short Time and Long Time Operations with Faults Present

	Short Time Faults		Long Time Faults	
Experience Level	Time of fault occurrence known and MEL Maintenance Approach Used – max operating time with fault(s) present	Time of fault occurrence unknown and Periodic Inspection/ Repair Maintenance Approach Used – max periodic inspection/repair interval	Time of fault occurrence known and MEL Maintenance Approach Used – max operating time with fault(s) present	Time of fault occurrence unknown and Periodic Inspection/ Repair Maintenance Approach Used – max periodic inspection/repair interval
Entry Level	125 flt. hrs.	250 flt. hrs.	250 flt. hrs.	500 flt. hrs.
Mature Level	(1)	(1)	(1)	(1)

(1) Times vary depending upon the system, analysis and service experience.

Figure 1. Typical Data Presentation Showing LOTC Rate as a Function of Short Time (ST) and Long Time (LT) Operating Hours

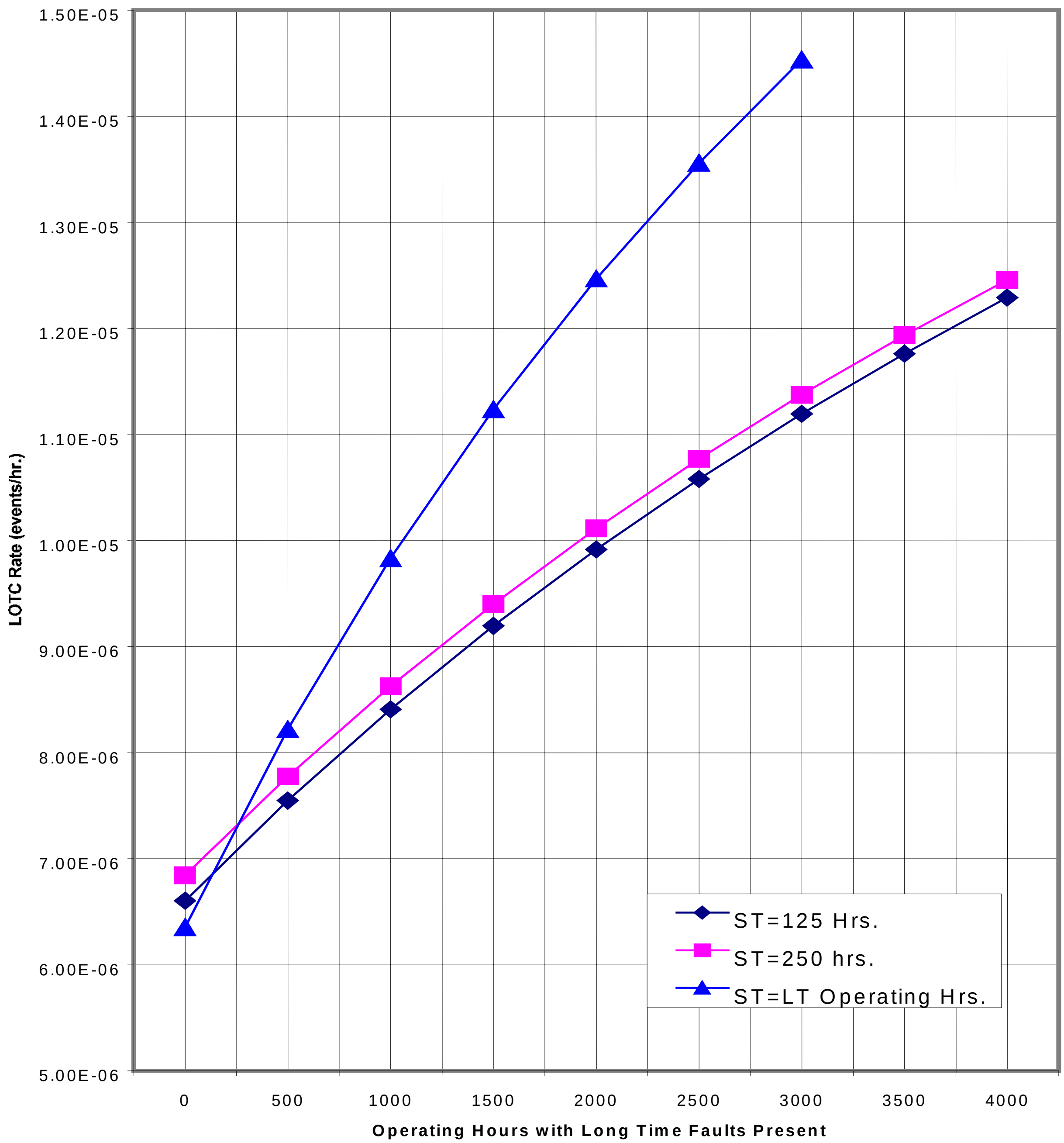
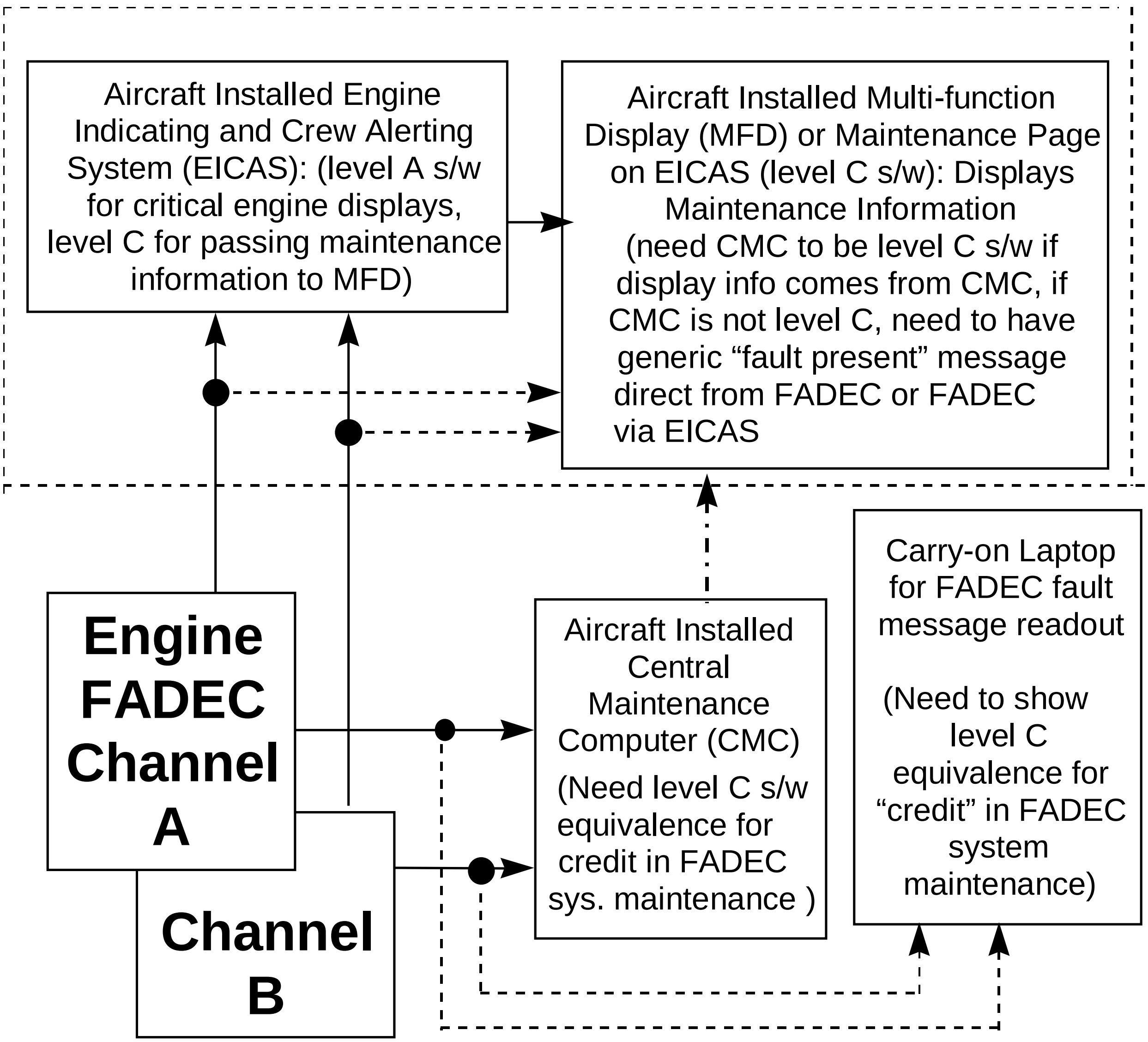


Figure 2. Typical Aircraft System Configuration(s).
Typical EICAS System with Multi-function Display



Note: "Levels A & C s/w" refers to a software development assurance equivalent to that process given in DO-178B for levels A & C software, respectively.